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(54) A microstrip resonator tunable filter and related tuning method

(57) A microstrip multi-resonator tunable filter (F) includes:

- a substrate (1) having arranged thereon one or a plurality of a microstrip resonators (3), and
- a dielectric element (4) arranged facing the microstrip resonators (3) at a selectively variable distance (D) to the substrate (1).

Varying that distance (D) permits to uniformly vary the resonating frequency of the microstrip resonators (3).

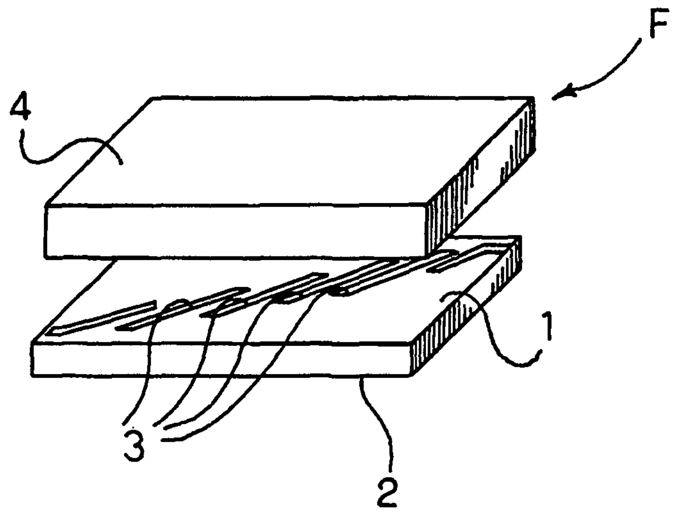

Fig. 1

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Description

Field of the invention

[0001] The invention relates to microstrip resonator tunable filters.

[0002] The invention has been developed by paying specific attention to the possible application to microwave transceivers such as e.g. outdoor unit microwave transceivers. However, reference to this preferred field of application is in no way to be construed in a limiting sense of the scope of the invention.

Description of the related art

[0003] Microstrip multi-resonator filters are well known in the art as witnessed e.g. by SU-A-1 026 203. Specifically, the prior art document in question discloses a filter including quarter wavelength strip resonators. Each quarter wavelength strip resonator is comprised of several coupled conductors, the shorted ends of which are connected to an earthing base, which is positioned on the opposite side of the dielectric substrate. The input signal is applied to one outer (edge) conductor, and the output signal is derived from the second edge conductor. A nominal 50 Ohm load is matched by a partial insertion (conductive coupling), and the filter selectivity is defined by the mutual positions of the conductors. Each resonator with shorted and open ends has two attenuation poles.

[0004] Microstrip tunable filters are typically used in the place of mechanical filters and antenna diplexers in microwave transceivers up to the 80 GHz frequency range. An antenna circulator and a proper number of filters arranged in a line-up front-end circuit permit the required selectivity to be reached while reducing the final insertion loss and the noise figure.

[0005] Within that context of use, a technical problem arises in expanding (e.g. doubling or more) the frequency operability of outdoor unit microwave transceiver by using the same microstrip multi-resonator tunable filter, while avoiding mechanically tunable arrangements, which are largely unpractical.

[0006] That problem has been solved up to now by changing the filters, that is by using a given filter for each frequency range: if the frequency range changes, the filter must correspondingly change. Since a given code is allotted to each filter at the industrial level, this solution inevitably leads to a large number of execution codes.

[0007] Mechanically tunable filters are similarly known where the tuning frequency of each resonator and the coupling between resonators are adjusted by means of screws.

[0008] Finally, arrangements for changing of the dielectric permittivity of capacitors are known in the art based on the use of BST (Barium-Strontium-Titanate) elements, as witnessed e.g. by A.S.Nagra and R.A York, "Distributed analog phase shifter with low insertion loss" IEE Trans. Microwave Theory Tech., vol47, pp1705-1711, sept 1999.

[0009] BST elements are ferroelectric elements that may change their permittivity as a function of a field to which they are exposed. Varying appreciably the dielectric constant of these elements requires electrical fields of the order of some tens Kvolt/mm. Machining and depositing these materials with thicknesses of the order on one micron is difficult due to the high crystallization temperature with the ensuing diffusion of the underlying conductive materials that form the transmission lines.

[0010] While steadily improving, this technology is not suitable for tuning microstrip filters in view of the very high electric fields required for a uniform dielectric permittivity distribution.

Object and summary of the invention

[0011] The object of the invention is thus to provide an improved arrangement that effectively dispenses with the drawbacks intrinsic to the prior art considered in the foregoing.

[0012] According to the present invention, that object is achieved by means of an arrangement having the features set forth in the claims that follow. The invention also concerns a related method. The claims are an integral part of the disclosure of the present invention as provided herein.

[0013] A particularly preferred embodiment of the invention is based on the concept of changing the effective dielectric constant of a set of microstrip multi-resonator filters by placing a dielectric planar material in close proximity of the filter surface, and varying the central working filter frequency by selectively changing the distance of the dielectric material to the filter surface. In that way, a single tuning element may uniformly tune all the resonators, while preserving the other electrical characteristics of the filters. Such operation can be easily performed whenever required, without having to disassemble, reassemble, test and measure again the filter arrangement.

[0014] An arrangement as described herein lends itself to be applied to filters embedded in printed circuit board (PCB) microwave circuits. This with a lay-out that may cover all the frequency diplexing gamuts (ranges) by easily tuning the filters in the working frequency band. This leads to significant advantages in terms of reduced material costs, manufacturing time and execution codes number, thus facilitating cost-effective production.

[0015] Advantageously, the claimed method is particularly adapted to tune a plurality of microstrip resonators, but without departing from the ambit of the invention may be profitably used for tuning a single microstrip resonator.

Brief description of the annexed drawings

[0016] The invention will now be described, by way of example only, with reference to the annexed figures of drawing, wherein:

- Figure 1 is a schematic perspective view of a filter arrangement as described herein,
- Figures 2 to 4 are representative of various tuning options available for the filter arrangement as described herein, and
- Figure 5 is diagram representative of performance of the arrangement described herein.

Detailed description of preferred embodiments of the invention

[0017] Figure 1 of the annexed drawings shows a microstrip filter F including a dielectric substrate 1 - e.g. an alumina (AL_2O_3) substrate - having a conductive (e.g. metal) ground plane 2 on is bottom face.

[0018] One or a plurality of coupled microstrip resonators 3 (i.e. at least one microstrip resonator) are laid e.g. by resorting to thin or thick film technology on the top surface of the substrate 1.

[0019] A tuning dielectric element 4, comprised of a thin parallelepiped body of FR4 (a current designation for glass-fiber based material used e.g. in manufacturing printed circuit boards or PCBs), polytetrafluoroethylene (PTFE or Teflon), or quartz is arranged parallel to the substrate 1 facing the resonators 3.

[0020] These materials are indicated herein as presently preferred examples of dielectric materials adapted for use within the framework of the invention. However, those of skill in the art will appreciate that the scope of the invention encompasses the use of any suitable dielectric material.

[0021] The distance between the substrate 1, namely the resonators 3, and the tuning element 4 can be selectively varied in order to change the central working filter frequency and thus uniformly tune all the resonators 3.

[0022] That result can be achieved in different ways, some of which are shown by way of example in figures 2 to 4. Essentially, all the embodiments shown rely on the concept of uniformly increasing/decreasing the effective dielectric constant associated with each and every resonator 3 by decreasing/increasing the distance of the dielectric planar material 4 to the filter surface.

[0023] Figure 2 is exemplary of an arrangement for mechanical continuous tuning of the filter F.

[0024] To that effect, the substrate 1 carrying the resonators 3 is arranged between a base plate 12 and a lid 14. The plate 12 and the lid 14 are maintained at a fixed distance by spacers 16, as schematically shown in Figure 2a. Figure 2a is a cross sectional view along line II-II of Figure 2.

[0025] A screw 18 in the form of e.g. a flat-tip dielectric screw or dielectric-ended metal screw is arranged in a threaded hole formed in the lid 14. Tightening or loosening the screw 18, that in any case represents a planar-ended dielectric element, causes a variation of the distance of the dielectric or dielectric-ended screw 18 to the substrate 1 in the region where the resonators 3 are arranged. The dielectric or dielectric-ended screw 18 thus plays the role of the dielectric element 4 of Figure 1.

[0026] Tightening or loosening the screw 18 causes the resonating frequencies of the filters provided on the substrate 1 to be uniformly varied as a result of uniformly increasing/decreasing the effective dielectric constant associated with each and every resonator 3.

[0027] Figure 3 is exemplary of an arrangement for piezoelectric tuning of the filter F. In Figure 3 elements or parts identical of equivalent to elements or parts already described in connection with Figure 2 are indicated by the same reference numerals.

[0028] In the arrangement of Figure 3, the screw 18 of Figure 2 is replaced by a piezoelectric element 20 carried by the lid 14. Typically, the element 20 is mounted at the lower surface of the lid 14 and carries in turn at its lower a dielectric plate comprising the dielectric element 4 of Figure 1. Controlling the piezoelectric element 20 (in a manner known per se, e.g. by controlling the voltage applied across its opposed surfaces via a bias line 20a - see Figure 4a) produces a controlled deformation of the element 20 and thus a controlled variation of the distance of the plate 4 to the substrate 1.

[0029] Again, this causes the resonating frequencies of the filters provided on the substrate 1 to be uniformly varied as a result of uniformly increasing/decreasing the effective dielectric constant associated with each and every resonator 3. Again, Figure 3a is a cross sectional view along line III-III of Figure 3.

[0030] Figure 4 is exemplary of another arrangement for tuning the filter F. Again, in Figure 4 elements or parts identical of equivalent to elements or parts already described in connection with Figures 2 and 3 are indicated by the same reference numerals. Similarly, Figure 4a is a cross sectional view along line IV-IV of Figure 4.

[0031] In the arrangement of Figure 4, a source of electromagnetic force 22 (such as e.g. a permanent magnet or an electromagnet powered by an external circuit - not shown) acts on a ferromagnetic disc or plate 24 placed at the upper end of a dielectric element 4, here in the form of a small cylinder of a dielectric material. A helical spring 26 interposed between the magnet 22 and the disc 24, having preferably associated a centering ferrule 28, allows two stable configurations of the magnet/disc assembly, namely:

- the disc 24 (and thus the dielectric element 4) is attracted to the magnet 22 with a force enough to win the reaction of the spring 26, or
- the force of the spring 26 is enough to keep the disc 24 (and thus the dielectric element 4) detached from the magnet 22.

[0032] The two resulting positions of the dielectric 4 to the substrate 1 essentially correspond to a bi-stable tuning of the filter F at two extreme tuning frequencies. These positions and thus the resulting frequencies can be adjusted and switching between the two can thus be easily obtained.

[0033] The diagrams of Figure 5 report the result of measurements performed by the Applicants. Specifically, the diagram in question shows the tuning frequency f (MHz - ordinate scale) of a filter F as shown in Figures 1 to 4, as a function of the distance D (mm - abscissa scale) between the substrate 1 and the dielectric tuning element 4. Specifically, three curves are shown for a tuning element of a glass-fiber based material (FR4), a polytetrafluoroethylene (PTFE or Teflon) tuning element and a quartz tuning element. The experimental measures clearly confirm that the tuned filter frequency is a function of the proximity of the dielectric element 4 to the surface of the microstrip resonators 3.

[0034] The measurements were performed on existing circuits designed to have very small size and not minimum losses and good selectivity. The measurements show that the appreciable tuning properties of the filter arrangements shown herein do in no way adversely affect the electrical characteristic thereof. A small increasing loss (0.3 dB) has been observed in the case of a dielectric tuning material of poor quality such as FR4. No additional losses were measured if PTFE (Teflon) or quartz are used as the tuning dielectrics. The measurements thus confirm the possibility of effectively controlling the tuned filter frequency by acting on the dielectric proximity to the microstrip resonator surface.

[0035] Tuning up to 10% of the central frequency was shown to be feasible depending on the permittivity of the moving element used for tuning. In fact, the dielectric constant or permittivity of the moving element used for tuning determines, all the other parameters remaining the same, a smaller or larger frequency shift.

[0036] Without prejudice to the underlying principles of the invention, the embodiments and details may vary, also significantly, with respect to what has been described by way of example only, without departing from the scope of the invention as defined by the claims that follow.

Claims

1. A microstrip filter (F), including:

   - a substrate (1) having at least one microstrip resonator (3) arranged on said substrate (1),
   - a dielectric element (4) arranged facing said at least one microstrip resonator (3) at a selectively variable distance (D) to said substrate (1), whereby varying said distance (D) varies the resonating frequency of said at least one microstrip resonator (3).

2. The filter of claim 1, **characterized in that** said substrate (1) is a planar substrate.

3. The filter of either of claims 1 or 2, **characterized in that** said substrate (1) is a dielectric substrate.

4. The filter of claim 3, **characterized in that** said substrate (1) has a conductive ground plane (2) arranged opposite said at least one microstrip resonator (3) with respect to said substrate (1).

5. The filter of any of the previous claims, **characterized in that** said dielectric element (4) is comprised of dielectric material selected from the group consisting of glass-fiber based material (FR4), polytetrafluoroethylene, and quartz.

6. The filter of any of the previous claims, **characterized in that** said dielectric element is a planar element (4) or planar-ended element (18).

7. The filter of any of the previous claims, **characterized in that** it includes a lid (12) arranged facing said at least one microstrip resonator (3) on said substrate (1) and a screw (18) carried by said lid (14), said screw (18) being at least partly comprised of said dielectric element (4), whereby tightening or loosening said screw causes a variation of the distance (D) of said dielectric element (4) to said substrate (1) and said at least one microstrip resonator (3).

8. The filter of any of claims 1 to 6, **characterized in that** it includes a piezoelectric element (20) supported (14) with respect to said substrate (1), said piezoelectric element (20) carrying said dielectric element (4) whereby piezoelectrically deforming said piezoelectric element (20) varies the distance of said dielectric element (4) to said substrate (1) and said at least one microstrip resonator (3).

9. The filter of claim 8, **characterized in that** it includes a lid (14) arranged facing said at least one microstrip resonator (3) on said substrate (1), said lid (14) carrying said piezoelectric element (20).

10. The filter of any of claims 1 to 6, **characterized in that** it includes:

    - a source (22) of magnetic force,
    - a ferromagnetic element (24) solidly associated with said dielectric element (4), said ferromagnetic element (24) being exposed to the action of said force (22) of magnetic force, and
    - a spring element (26) interposed between said source of magnetic force (22) and said ferromagnetic element (24),

    the arrangement being such that said ferromagnetic element (24) and thus said dielectric element (4) are adapted to assume two different positions depending on whether the force of said source of magnetic force (22) or the force of said spring element (26) prevails, said two different positions corresponding to two values of said distance of said dielectric element (4) to said substrate (1) and said at least one microstrip resonator (3).

11. The filter of claim 10, **characterized in that** said dielectric element (4) is in the form of cylinder.

12. The filter of either of claims 10 or 11, **characterized in that** said source of magnetic force is a magnet such as a permanent magnet (22).

13. The filter of any of the previous claims, **characterized in that** it includes a plurality of microstrip resonators (3) arranged on said substrate (1), whereby varying said distance (D) of said dielectric element (4) to said substrate (1) uniformly varies the resonating frequency of the microstrip resonators (3) of said pulrality.

14. A method of tuning a microstrip filter (F) including a substrate (1) having at least one microstrip resonator (3) arranged on said substrate (1), the method including the steps of:

- arranging a dielectric element (4) facing said at least one microstrip resonator (3) at a distance (D) to said substrate (1), and
- selectively varying said distance (D) of said dielectric element (4) to said substrate (1), whereby varying said distance (D) varies the resonating frequency of said at least one microstrip resonator (3).

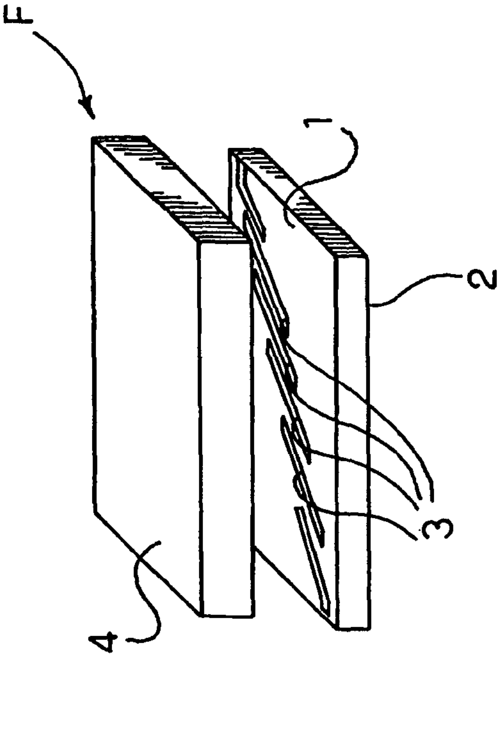

F
1
2
3
4

Fig_1

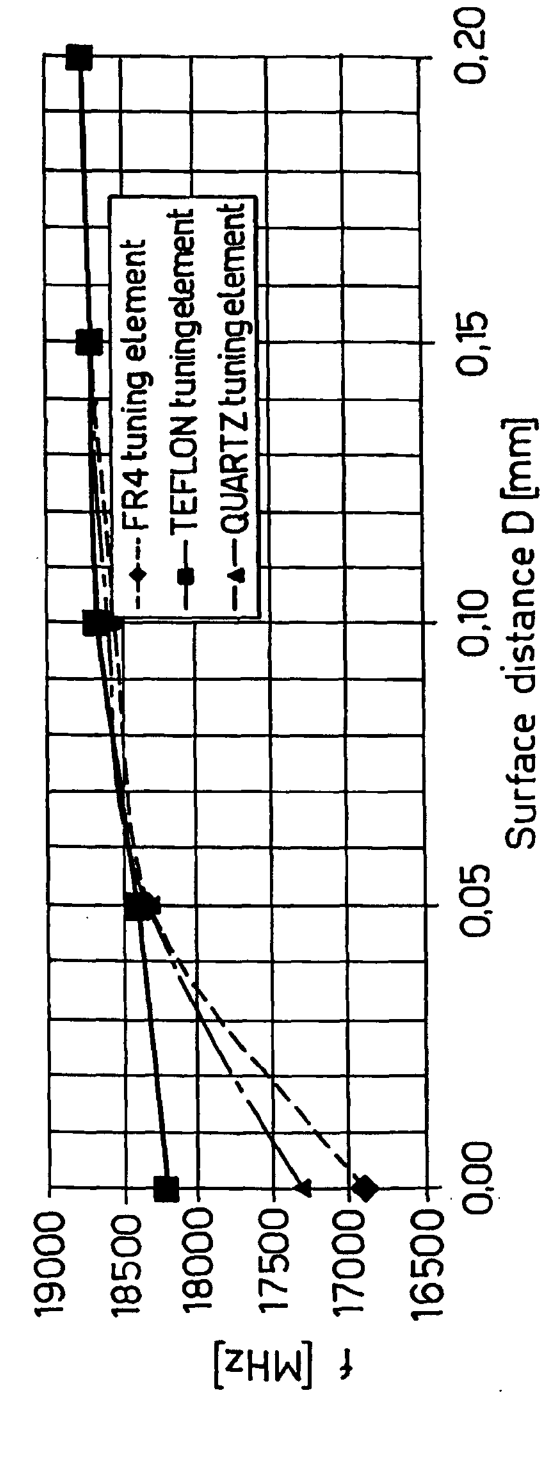

f [MHz]
19000
18500
18000
17500
17000
16500
0,00
0,05
0,10
0,15
0,20
Surface distance D [mm]
FR4 tuning element
TEFLON tuningelement
QUARTZ tuningelement

Fig_5

Fig_2

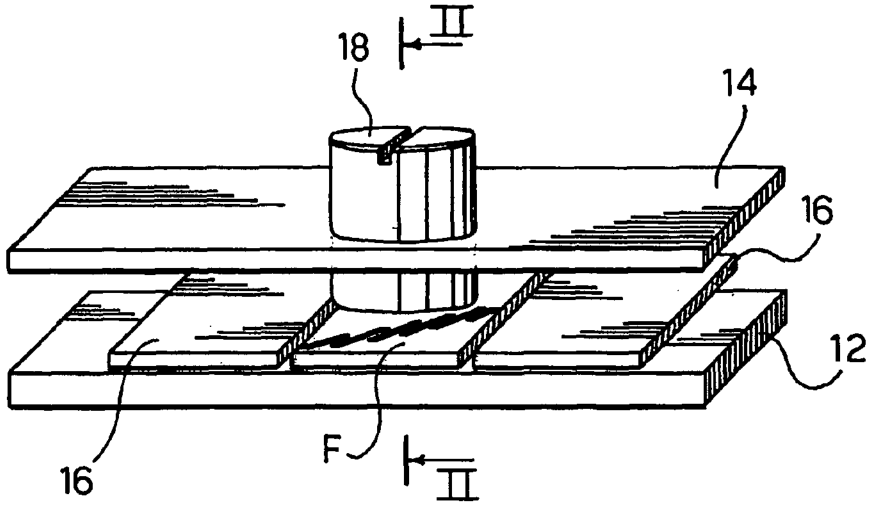


Fig_2a

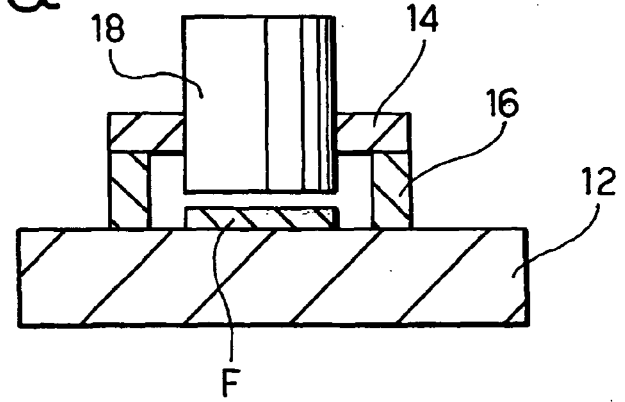


Fig_3

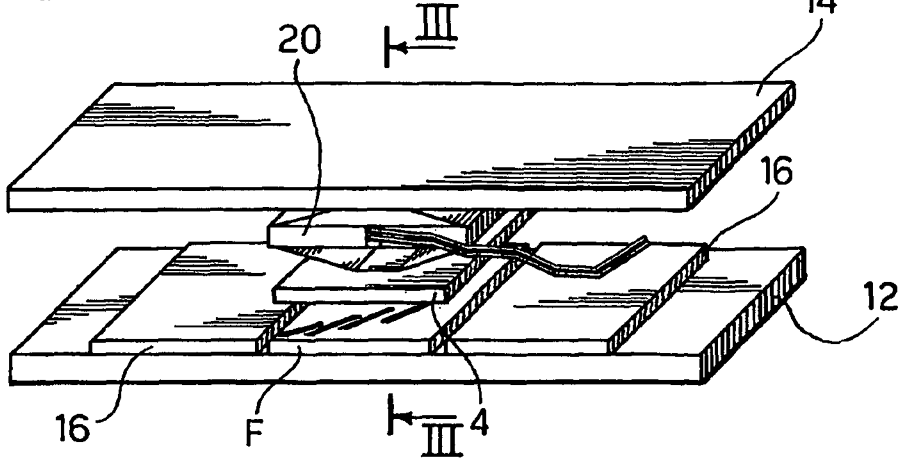


Fig. 3a

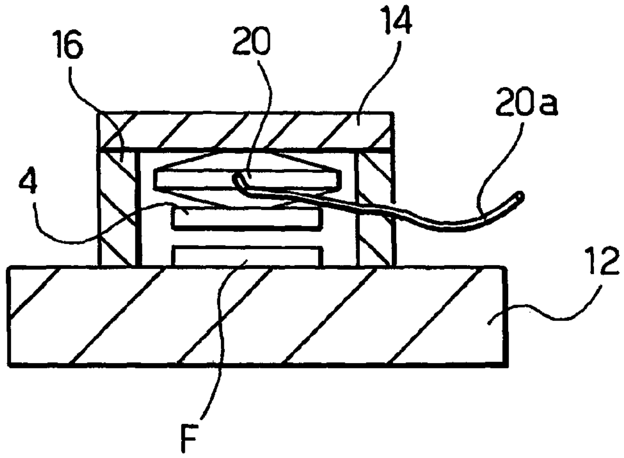


Fig. 4

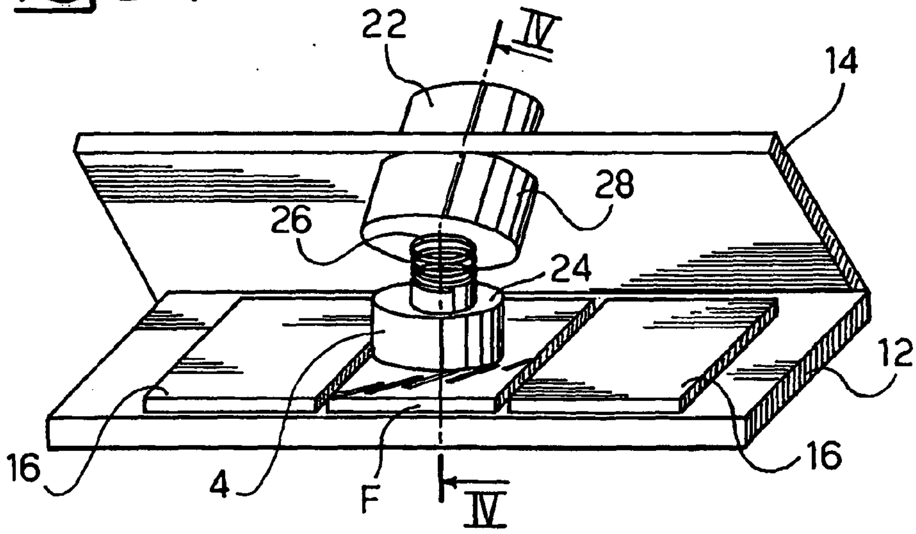
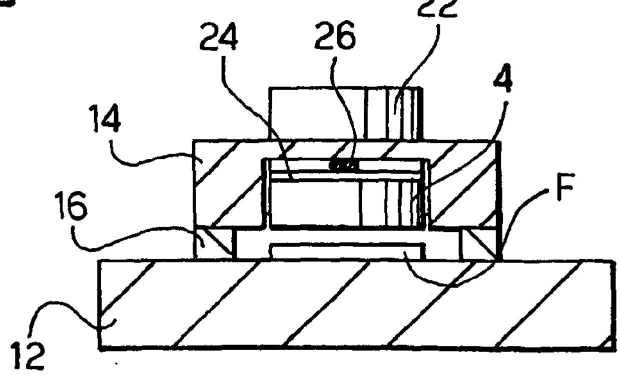


Fig. 4a



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EUROPEAN SEARCH REPORT

Application Number
EP 04 42 5815

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X	EP 1 202 375 A (KABUSHIKI KAISHA TOSHIBA) 2 May 2002 (2002-05-02) * paragraph [0001] * * paragraph [0011] * * paragraphs [0030] - [0034]; figure 1 * * paragraph [0065]; figures 6,7A,7B * * paragraphs [0093] - [0097]; figure 21 * * paragraph [0133]; figure 30 *	1-4,6,7, 10-14	H01P1/203
Y	-----	5,8,9	
Y	EP 1 376 745 A (HARRIS CORPORATION) 2 January 2004 (2004-01-02) * paragraph [0014] * -----	5	
Y	PATENT ABSTRACTS OF JAPAN vol. 017, no. 241 (E-1364), 14 May 1993 (1993-05-14) & JP 04 368006 A (NIPPON TELEGR & TELEPH CORP <NTT>), 21 December 1992 (1992-12-21) * abstract * -----	8,9	
A	US 2003/122635 A1 (BORZENETS VALERY ET AL) 3 July 2003 (2003-07-03) * paragraphs [0042] - [0051]; figure 1 * -----	1-14	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H01P

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	9 March 2005	Pastor Jiménez, J-V

CATEGORY OF CITED DOCUMENTS

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